



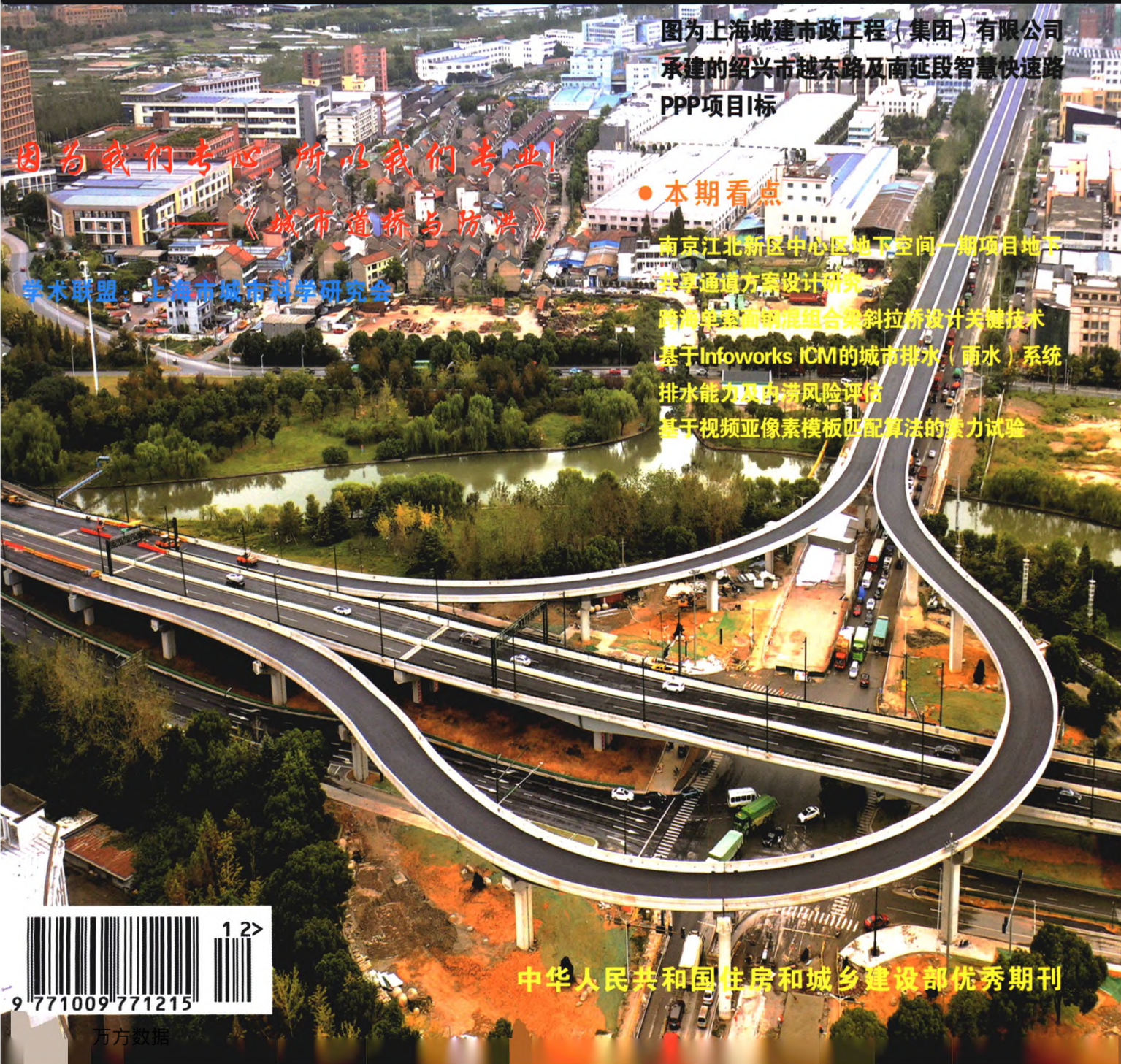
# 城市道桥与防洪

主管：中华人民共和国住房和城乡建设部  
主办：上海市政工程设计研究总院(集团)有限公司

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——《城市道桥与防洪》

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- 跨海单索面钢混组合梁斜拉桥设计关键技术
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中华人民共和国住房和城乡建设部优秀期刊

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**封面工程**

本期封面工程为绍兴市越东路及南延段智慧快速路 PPP 项目,由上海城建市政工程(集团)有限公司承建 I 标。I 标工程北起杭甬高速,沿中兴大道、三江路、越东路向南至越东路凤林路交叉口,工程范围内快速路主线总长约 9.2 km。道路断面形式为“主线高架+地面辅路”。中兴大道主线高架标准段采用双向 4 车道,三江路主线高架标准段采用双向 4 车道,越东路主线高架标准段采用双向 6 车道,地面辅道标准段采用双向 6 车道,工程总造价约 23.97 亿元。

该工程为杭州亚运会重点配套项目,是绍兴市第一条智慧快速路,也是绍兴市“六横六纵”快速路网的重要组成部分。项目实施标准化设计、工厂化制造、装配式施工、信息化管理的建设方法,分别采用了预制构件、大悬臂盖梁两节段“反拉法”施工、液压自平衡吊具、现浇盖梁无落地支架、改性聚氨酯混凝土、预制空心立柱、钢与混凝土组合结构应用、大跨径超重钢箱梁提升、超高性能混凝土 UHPC 等多种创新性工程技术;通过融合 BIM 技术、5G 现代通信网络、智能芯片等,实现网联车测试系统、智慧云控制平台等先进功能;采用先进的智慧交通管理技术,实现无人驾驶,全面打造“智能、快速、绿色、安全”的智慧快速路。

项目于 2018 年 12 月 8 日开工,其中中兴大道主线高架和中兴大道地面道路已于 2021 年实现通车。

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# Urban Roads, Bridges & Flood Control

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**Abstract:** With the construction and development of urban core business districts (CBD) in China, how to rationally allocate the vacant parking spaces in various garages and maximize the utilization of parking resources is an urgent problem to solve. In the study on the design of Nanjing Jiangbei New District Central Area Underground Space Phase I Project, a circular shared passage for the underground cars is designed, and the underground parking resources are connected and integrated in order to improve the service efficiency of the garage. At the same time, the entrances and exits connected to the municipal roads are used to quickly divert some car traffic entering and exiting the underground garage, thereby reducing the road traffic pressure on the ground and improving the traffic service quality of CBD. Two design schemes of "one-ring two-connection" ring scheme and "one-line six-connection" tree-shaped scheme are proposed, and compared and analyzed from the aspects of traffic function, connected land number, garage sharing engineering, implementation process and engineering cost. The analysis result shows that the "one-ring two-connection" ring scheme can more effectively connect and integrate the underground parking resource in the area and improve the service efficiency of garage.

**Keywords:** underground space, underground shared passage, scheme design

Overall Scheme Design of Ganzhou City Wenming Avenue Expressway Project ..... LI Daxu ( 4 )

**Abstract:** Wenming Avenue Expressway in Ganzhou City of Jiangxi Province is an important horizontal part in the "one-ring", four-horizontal" and "six-vertical" expressway network system of the central urban area in Ganzhou, which is in the east - west trend. Its total length is about 6.48 km. It is mainly the elevated bridge including the elevated road and ground road, and spans Zhangjiang River and Beijing - Ckowlonn Railway with an interchange. Aiming at the problems of expressway passing through the core area of old city, large construction scale, complex engineering and limited red-line land, combined with the main control conditions, the main technical standards and overall design scheme are determined. The overall layout, important node comparison and plane - vertical - horizontal design of the expressway are special introduced, which provides the reference for the similar expressway projects.

**Keywords:** expressway, old urban area, overall design, cross-section layout, elevated bridge

Overall Design of Jinjianhuang Expressway North Extension Section Project .....  
..... GONG Wei, HE Jianrong ( 8 )

**Abstract:** Jinjianhuang Expressway is an important part of the "nine-horizontal six-vertical" expressway network in the eastern new area of Chengdu. Its north extension section is the controlling project of this expressway. Aiming at the difficulties of more control nodes, complex engineering design and high

landscape feature of Jinjianhuang Expressway North Extension Section, the schemes of cross-section overall layout, key node design and road landscape of the project are introduced in detail from the analysis of functional orientation, which provides the reference for the design and construction of the similar projects.

**Keywords:** expressway, overall design, node scheme, road landscape

Research on Planning and Design Method and Engineering Application of Urban Road Cross Section ..... ZHOU Huaien, GAO Peng ( 10 )

**Abstract:** With the acceleration of urban economic development at this stage, the hardening area increases year by year in the construction of urban roads, which leads to the reduction of urban permeable surface, is likely to cause the urban waterlogging and other disasters during the rainy season, and will bring many problems to the urban development and residents' lives. In order to reduce the occurrence of urban waterlogging and other problems, in the process of urban road cross-section planning and design, combined with the construction concept of sponge city, the corresponding design methods are proposed to guide the engineering application. The design goals of the sponge-type urban roads are clarified. The features of various LID measures in terms of function, control goals, economy, impact on surrounding plots, and landscape effects are analyzed. The cross section design methods of the roads with the red line widths of 12~15 m, 20~28 m, 34~40 m and above 40 m are expounded.

**Keywords:** urban road, road design, cross section, LID measures, sponge city

Discussion on Design Standard of Turning Radius at Grade Intersection of Urban Road ..... ZHANG Zhihao, ZHANG Cheng ( 13 )

**Abstract:** In the design of turning radius at grade intersection of urban road, the designers often do not know how to select more scientific numerical values because there are few descriptions in relevant specifications and the actual situation is more complex. Based on the comparison of domestic and foreign technical standards, combined with the practical engineering experience, the valuing method of turning radius at grade intersection of urban road is analyzed in order to provide some reference for the related road designers.

**Keywords:** urban road, turning radius, technical standard

Research on Forecasting Method of Passenger Flow Scale in Large Theme Park of Xi'an Children's World Park Project ..... XU Guomiao, YANG Hu ( 15 )

**Abstract:** In order to study the forecasting method of passenger flow in large theme parks, taking the passenger flow forecast of Xi'an Children's World Park as an example, the basic analysis method of passenger flow forecasting in large theme park is proposed. The spatial distribution characteristics of passenger flow are analyzed from three factors of population, economy and traffic by starting from the prediction of overall scale of regional tourist market. The market penetration indicators closely related to the product characteristics are introduced to forecast the total annual passenger flow of theme park.

**Keywords:** theme park, passenger flow scale, market distribution, market penetration

Study on Existing Problems and Improvement Measures for Signing and Marking of Municipal Road ..... WANG Lei, NI Na ( 18 )

**Abstract:** With the transfer of rural population to cities, the municipal engineering construction is becoming more and more rapid, in which the investment in the urban roads convenient for citizens to travel and transport is increasing year by year. With the increasing frequency of the use of municipal roads, the signings and markings playing the role of warning and indication expose some problems that need to be solved urgently, which seriously affect the function and comfort of municipal roads. Based on a detailed analysis

of the existing problems and impacts of the signings and markings of municipal road engineering in China, the targeted improvement measures are proposed to ensure the perfection of the functions of signings and markings and improve the efficiency of vehicle traffic, which escort the safety, convenience and comfort of municipal road engineering.

**Keywords:** municipal road, signings and markings, problems, improvement measures

Brief Discussion on Treatment of Large-thickness Fill Subgrade in Collapsible Loess Area .....  
..... LIU Shungui, KANG Lianguo, TONG Jingsheng ( 21 )

**Abstract:** The current "Code for Design of Highway Subgrades" and "Code for Design of Urban Road Subgrades" all draw on the relevant contents of the "Building Standards for Collapsible Loess Areas" for the ideas and principles of collapsibility treatment. Due to the high requirements of buildings on deformation and bearing capacity, the collapsibility of the foundation shall be completely treated according to the different levels of buildings and the pile foundation shall be used to traverse the entire loess layer. The building occupies a small area, and it is necessary and reasonable to treat the collapsibility of the foundation completely or to penetrate the loess layer with the pile foundation. However, for highways, urban roads, sites and other projects with large areas and low requirements for foundation deformation and bearing capacity, all collapsibility is treated in accordance with the relevant requirements of the "Building Standards for Collapsible Loess Areas", which is the exiting feasible, economical and reasonable problem. The influence of the large-thickness fill collapsibility on the project is mainly insufficient bearing capacity and overlarge deformation, which can be solved by taking some engineering measures. The problem of large-thickness collapsibility is changed into the issue of controlling the settlement and deformation of subgrade to realize the contradiction conversion and problem simplification in order to achieve the effect of solving the problems in the range of full fill thickness. Based on the large-thickness loess landfill sites, with increasing burial depth, the soil compactness will gradually increase, and with increasing burial depth, the probability of soil being wetted by water gradually decreases. The targeted engineering scheme is designed to make the treatment method, scope, standard and degree of the large-thickness fill collapsibility reasonable and economical, which are the immediate problems.

**Keywords:** large-thickness loess fill, collapsibility, settlement, deformation

Speculation on Design of Rural Road Traffic Safety Facilities ..... LUO Miaoping, LI Shu ( 26 )

**Abstract:** By analyzing the traffic characteristics of rural roads, the reasonable range of rural road design speed is determined. The traffic safety facilities suitable for the rural roads are analyzed. And combined with the relevant experience of Wengyuan Project, some typical node design examples are summarized, which can provide a useful reference for traffic safety design of the other rural road projects in rural revitalization construction in the future.

**Keywords:** rural road, traffic safety, rural revitalization

## BRIDGES & STRUCTURES

Key Design Techniques of Single-plane Steel-concrete Composite Girder Cable-stayed Bridge for Crossing Sea ..... YANG Chengfeng, WANG Shaoxun, GAO Enquan ( 31 )

**Abstract:** The main bridge of Fuchimen Bridge is a 57 m + 108 m + 340 m + 108 m + 57 m double-pylon single-plane steel-concrete composite girder cable-stayed bridge. The main girder is a single-box three-cell steel-concrete composite girder. The standard section is 27.5 m wide. The side span is located in the interchange widening section and the main girder is widened to 35.5 m. The segmental precasting and cantilever assembling are used to construct the main girder. The finite element model is established

by using a analysis software of Midas/civil to carry out the anti-wind stability analysis in the maximum cantilever stage and operation stage of bridge construction. To ensure the structural durability in marine environment, the performance of marine concrete, the thickness of reinforced protective layer, the concrete admixture, the dehumidification of steel girder and the anti-corrosive coating are clearly required. And the perfective maintaining and service facilities are set up.

**Keywords:** cable-stayed bridge, steel-concrete composite girder, single-box three-cell box girder, variable width of main girder, wind resistant stability, durability, design

Practical Method to Determine Reasonable Cable Force of Complex Cable-stayed Bridge .....  
..... SUN Xuxia ( 34 )

**Abstract:** In view of the difficult problems of complex cable adjustment in landscape cable-stayed bridge, taking a spatial twisted pylon cable-stayed bridge as an example, a practical method of cable force optimization is proposed. The method can realize the intuitive and adjustable multi-objective cable force optimization, which is not limited by the program and can quickly determine the reasonable cable force. The method can also realize the subjective controllability of the designers, and help the designers quickly grasp the structure association characteristics while adjusting the cables.

**Keywords:** cable-stayed bridge with twisted cable plane, multi-objective optimization of cable force, reasonable cable force of completed bridge, computing method

Design and Stress Analysis of Large Tonnage Hinged Support of Two-hinge Steel Structural Arch Bridge .....  
..... REN Qingshun, ZHENG Aihua, WANG Meixin ( 38 )

**Abstract:** As the main bearing structure of two-hinge arch bridge, the arch hinge support is the key part of connecting the arch foot and abutment, and is the key link of control design. Because the hinge structure cannot be replaceable and is exposed to the air, the hinge structure is bound to be corroded by water and air. At the same time, due to the large tonnage and large stress, there is bound to be stress corrosion. Taking the arch hinge of Tianbaowan Bridge as an example, the 5 500-ton high-strength brass arch hinge is used for the first time in China. The arch hinge should be smooth in the force transmission, the stress distribution is reasonable and there is no stress concentration. The local stress of arch hinge of Tianbaowan Bridge is analyzed and calculated to verify the rationality and feasibility of its design.

**Keywords:** structural design of arch hinge support, simulation analysis, durability

Research on Scheme of Large Bridge Overpassing Railway in Urban Rail Transit .....  
..... WU Liang, WANG Lunwen, ZHAO Yinru ( 41 )

**Abstract:** The bridge overpassing railway in Wuhan Rail Transit Line 7 North Extension Project needs to span the multiple railways. Affected by the high limitation of Tianhe Airport, the main bridge is designed as a (86 + 2 × 156 + 86)-m prestressed continuous beam bridge. In the design, the residual creep deformation of the beam is reduced by increasing the beam height and adjusting the arrangement of prestressed steel strands. The crack resistance of the main beam web is improved by using the twice-tensioning vertical steel strand prestress system. In order to reduce the interference of construction on the existing railways, the rotation construction scheme is adopted, and the rotation tonnage is up to 15 000 t. The foundation pit of adjacent railway is supported by isolation piles, and the additional settlement of the existing railway subgrade at all stages of foundation pit excavation and bridge construction meets the specification requirements.

**Keywords:** rail transit, rotation construction, additional settlement, residual deformation, overpass bridge, isolation pile

Overall Design of Overpass Bridge on Shawan Road in Yichang City .....



- ..... WEI Shunbo, PAN Fan ( 45 )
- Abstract:** Shawan Road Overaa Bridge is an iconic landscape bridge in Yichang City Baiyang Port Logistics Park. It spans Baiyang Avenue. Its total length is 249.5 m. Its main bridge is a  $2 \times 74$  m single-plane cable-stayed bridge with a horizontal herringbone pylon and the asymmetrical one-sided arrangement. The main pylon and main beams are made of steel structure. The bridge deck pavement is casted of pouring asphalt concrete.
- Keywords:** landscape bridge, cable-stayed bridge, single-plane, herringbone pylon, steel pylon, steel box beam, pouring asphalt
- Design of Thin Beam in Widening of Ground Bridge ..... YIN Chengzhang ( 48 )
- Abstract:** Based on a rapid project in Shanghai, under the boundary constraint condition, the thin beam structure is used to widen the existing bridges in order to meet the needs of bridge mechanics and function, which provides an efficient solution for complexly widening bridges.
- Keywords:** widening bridge, thin beam, scheme design
- Study on Design Scheme of Hanjiang River Landscape Bridge in Ankang City .....  
..... SONG Dan, FENG Yang ( 51 )
- Abstract:** Ankang City is built along the Han River. The surrounding buildings of the bridge have the important historical and cultural significance. Both sides of the bridge are connected to the important streets and railway station of Anking City. The key research topics are the location direction of the landscape bridge, the integrating degree of the bridge type selection with the surrounding historical culture, and the connection of the landscape bridge with the roads at the both sides of Hanjiang River. The design scheme of Hanjiang River Landscape Bridge in Ankang City is studied from the aspects of design idea, functional positioning, bridge location comparison, bridge type schemes and cost.
- Keywords:** pedestrian landscape bridge, traffic connection, functional positioning, cable-stayed bridge, slow traffic system.
- Study on Stress Performance of Long Cantilever Suspension Covered Bridge .....  
..... ZENG Tianbao, ZHANG Lin ( 55 )
- Abstract:** The long cantilever glass suspension covered bridge with its novel shape has become the highlight of scenic spots to attract tourists. Taking the glass suspension covered bridge in Tonglu Chuiyun Tongtianhe Scenic Spot as an example, the structural stress of the bridge shows the complex spatial mechanical characteristics. In order to understand the stress characteristics of the bridge in detail, Midas/Civil is used to analyze its stress performance. By stress analysis, the overall stress performance of the bridge is good.
- Keywords:** long cantilever, suspension covered bridge, stress performance
- Research and Analysis on Mechanical Characteristics of Railway Rigid-frame Bridge .....  
..... CAO Huajie ( 58 )
- Abstract:** A rigid-frame bridge is widely used in crossing the existing roads because of its unique structural characteristics. Taking a new railway as the engineering background, according to the engineering situation of the site, the rigid-frame bridge with the different spans, clear height and skew angle is designed. Based on MIDAS plate element, the model is established to analyze the mechanical characteristics of the rigid-frame bridge, and then the reinforcement calculation is carried out to obtain more reasonable reinforcement calculation results, which can provide reference for the similar projects.
- Keywords:** rigid-frame bridge, span, clear height, skew angle, finite element model, mechanical characteristics, reinforcement calculation.

Seismic Analysis of Airport Viaduct Based on American Code .....

..... XIE Feng, WANG Weidong, SHU Pengyu, SUN Xianfeng ( 61 )

**Abstract:** In order to study the seismic response performance of the viaduct in front of the airport station according to American code, the influence of the bridge substructure is analyzed to guide the design of the viaduct. Taking a viaduct of a Southeast Asia airport as the study object, the model is established by using the finite element software to analyze the influence of its unconventional pier-column size on the seismic response of the overall bridge structure, and to check the ductile seismic design of the bridge. The results show that the variable section cylindrical piers with large top and small bottom are adopted, and the main beam adopts an integral box girder with a width of 32.8 m. Through the check of control section, it is shown that the pier bottom is the weaker section. The content can provide reference for the seismic engineering of other similar bridges.

**Keywords:** airport viaduct, bridge code of America, Anti-seismic

Brief Discussion on Design of Zhanlan Avenue Bridge Crossing River and Application of BIM Technique .....

..... PENG Fengqiang, RAN Wenmin, LI Liwei, ZHANG Yu, WANG Qingbin, GUO Zhenfeng, PENG Jian ( 64 )

**Abstract:** Based on the engineering background of Zhanlan Avenue Bridge (Zhanyun Bridge) crossing river in Shenzhen Airport New Town Start-up Area Integration Project, the design ideas, problems and solutions in the whole process of bridge design and construction are briefly discussed, and how to use BIM technology to solve various problems met in scheme design, construction drawing design, factory processing and on-site installation is expounded. The design ideas of landscape bridge and the application experience of BIM in design and construction are mainly introduced, which can provide some reference for the design and construction of other similar bridges in the future.

**Keywords:** BIM, steel structure, steel bridge, beam-arch composite bridge, bowstring arch bridge, Zhanyun Bridge

Analysis on Parameterization Design of Landscape Arch Bridge .....

..... QIAO Weiguo, QU Huiming, MA Yue ( 69 )

**Abstract:** In order to meet the traffic requirements of the crowd after the reconstruction of riverside landscape, two landscape arch bridges are designed in the Nixi River and the adjacent wetland area. When the relevant parameters of the arch bridge are preliminarily determined, the time to determine the final scheme is shortened by sorting and analyzing the design parameters of the existing projects. The design analysis process of the project has a certain reference value for other similar projects.

**Keywords:** landscape, parameter, design

## FLOOD CONTROL & DRAINAGE

Evaluation on Drainage Capacity and Waterlogging Risk of Urban Drainage (Rainwater) System Based on Infoworks ICM .....

LIU Huachao, LIANG Fengchao, XU Wei, ZHAO Rixiang, ZHOU Minhua ( 71 )

**Abstract:** In order to evaluate the drainage capacity and waterlogging risk of drainage (rainwater) system in LSH basin, a hydrodynamic model of drainage (rainwater) system in LSH basin is built based on Infoworks ICM. The drainage capacity and waterlogging risk of the current drainage (rainwater) system are evaluated, and the corresponding reconstruction scheme is proposed for an important region according to the evaluation result. And then the reconstruction scheme is simulated and verified through the model. The results show that the standard rate of drainage (rainwater) pipe network in LSH basin (meeting once every two years) is 68.4%. The rate of reaching the standard of

the whole pipeline is higher. If the drainage capacities of pipeline are less than 1-year once, 1~2-year once, 2~3-year once, 3~5-year once and larger than 5-year once, the proportions of pipe network are 18.5%, 13.12%, 42.35%, 15.38% and 10.65% respectively. There is a high risk of waterlogging in the southeast of LSH basin. Through the simulation verification of the reconstruction scheme of laying 1.2 m × 1.2 m rainwater pipe channel along the east side of Qizhou Road, it is shown that the reconstruction scheme can better solve the problem of waterlogging and ponding in the area of East Square.

**Keywords:** drainage capacity, waterlogging risk, Infoworks ICM, hydrodynamic model, reconstruction scheme

Discussion on Overall Design of New Urban Smart Drainage System ..... LI Yijun, ZHANG Wentao (75)

**Abstract:** The new smart drainage system is an important part of the new smart city. Based on the overall design of the new smart drainage system, the current situation of the drainage information system and the needs of different people for the smart drainage are analyzed. According to the "people-oriented" design concept, the overall design principles of demand orientation, scene guide, digital empower, business innovation, overall planning and step-by-step implementation of the new smart drainage system are expounded. The service architecture of three aspects of smart operation and maintenance, smart scheduling and smart service, and the technical architecture of six levels of perception executive level, ICT infrastructure level, data level and etc. are introduced.

**Keywords:** new smart city, smart drainage, overall design, service architecture, technical architecture

Study on Path and Mode of Sponge City Construction Systematically and Regionally Promoted in Eastern Counties for Wujin in Jiangsu ..... ZHU Lin (79)

**Abstract:** Taking the provincial sponge city construction pilot work in Wujin of Jiangsu as an example, the new path and new mode of the sponge city construction by the green low-carbon idea to guide the high quality development in the counties are explored. The important features of local urbanization taking counties as the carrier are reflected. The strategy of sponge city pilot construction and the mode of accurate pilot area in Wujin are expounded. The features of the sponge pilot construction systematically and regionally promoted in the typical counties of Wujin are summarized, and five kinds of valuable experience are purified, which can be referenced for the green low-carbon development of the other similar cities.

**Keywords:** sponge city, green low-carbon, urbanization, high-quality development, top-level design, industrial development

Study on Runoff Control Model of Sponge City ..... WANG Yong, ZHAO Ping, LIANG Zhenkai, HAO Xinyu (84)

**Abstract:** The annual total runoff control rate – the core index of sponge city can be elaborately calculated through the model. However, the establishment of the model needs to pay attention to the parameters and boundaries, and the generalization and rate determination are relevantly normalized. Therefore, in the modeling, the influences of rainfall sequence length and step length as well as the pipe network in the model generalization are considered to analyze. At the same time, the sensitive modeling parameters of permeability rate, impermeability, hardening area collection rate and different settings of evaporation are compared. The rate determination method is preliminarily explored. The conclusion can provide the reference for the establishment of runoff control models in the other sponge cities.

**Keywords:** sponge city, runoff control model, annual total runoff control rate, rainfall, generalization, parameter, rate determination

Typical Sponge Measures and Evaluation Methods for Road Design ..... LI Wanbai, DONG Pingyan, XIONG Huanwei ( 87 )

**Abstract:** In recent years, the large-scale urban construction has had a great negative impact on the ecological environment. In order to solve the problems of environmental pollution, water resource loss and ecological degradation, it is necessary to strengthen the construction of sponge city facilities in the road design. By analyzing and studying the typical measures of sponge cities such as the permeable paving, sunken green space, biological retention and grass-planting ditch, combined with the actual road engineering applications, the runoff control accounting methods are proposed, and a series of safe, effective, economical and applicable road sponge measures are summarized.

**Keywords:** sponge city, typical approach, sunken green space, runoff control

Study on Influence of Construction Site Foundation Pit Drainage on Water Environment and Countermeasure ..... ZHANG Minghao, FENG Chunmiao, XIE Xin, WANG Lei, YUAN Ping, ZHAO Liang ( 92 )

**Abstract:** Taking the foundation pit drainage of construction site in the south of Hexi in Jianye District, Nanjing as a study object, the present situation of foundation pit drainage and its influence on the water environment are analyzed. From the perspectives of formulating the group discharge standards, introducing the water governance agency, strengthening the drainage treatment monitoring and supervision, and building the intelligent construction sites, the pollution prevention and control countermeasures of foundation pit drainage are formulated, and the scientific and reasonable foundation pit drainage management model is explored, which provide the reference for the foundation pit drainage management in other similar areas.

**Keywords:** foundation pit drainage, groundwater, discharge standards, intelligent construction site

Brief Discussion on Planning of Water Ecological Restoration and Protection Project in Urban Area of Zhangye ..... ZHOU Binwu, CAO Jin, WEI Chengliang, HAN Bingbing ( 95 )

**Abstract:** Zhangye has an ancient reputation of "half a city reed half a city tower, a lake with flowers racing Jiangnan". Surrounded by a moat and connected by ponds and ponds, it is clear that its rich water system has created a good urban water ecology and wetland landscape. However, with the rapid development of the city, the water ecological environment in the urban area has been destroyed to a certain extent, especially in the southeast of the city. The present water system is mostly blocked by urban construction, and the water ecological environment is relatively fragile. Based on the analysis of the present situation and the study of the overall planning of Zhangye, the planning ideas of using the agricultural drainage of irrigation canal as the water source and constructing the water system around the city along the Third Ring Road are proposed. And through five strategies of the "ecological meltwater, dam retaining water, excavating catchment, scientific green water and waterways connection", the planning vision of "water moistening Zhangye, cultural city" is finally realized. Its effect can provide the reference for the water system planning of the other cities.

**Keywords:** urban area of Zhangye, water ecology, planning objective, planning idea, planning strategy

## MANAGEMENT & CONSTRUCTION

Research on Construction Method of Landscape Steel Bridge in Exhibition Avenue of Shenzhen Airport New City ..... LI Tan, ZHAO Bin, Duan Hong, WEN Yong, GENG Liang ( 99 )

**Abstract:** A landscape bridge in Exhibition Avenue of Shenzhen Airport New City is a new type of landscape steel bridge structure. Because of its unique shape, the stability of arch rib is poor before the structural system transformation. The common construction methods of "arch before beam" or "beam before arch" can not solve the contradiction between the construction safety and economy. Therefore, on the basis of the above two methods, this paper attempts to use the structural characteristics of the main

longitudinal beam, cross beam and bridge deck are attempted to use, and the method of arch and beam cross construction is used. On the premise of ensuring the construction safety, this problem is better solved, which can provide a reference for the construction of similar projects in the future.

**Keywords:** landscape steel bridge, simultaneous construction of arch and beam, construction method

Hole-forming Technology in Construction of Bridge Cast-in-situ Pile ..... WANG Junjian ( 103 )

**Abstract:** The cast-in-situ pile has become a bearing form widely used in the field of pile foundation engineering because of its characteristics such as high bearing capacity, good seismic performance and strong geological adaptability. Taking a bridge project as an example, the following three kinds of pile foundation obstructed in construction are studied. First, the steel pile casing is hard to be buried normally. Second, the steel pile casing is deformed or deflected in the drilling process. Third, the steel pile casing is hard to drill in the process of drilling encountered obstacles. In view of the above, the corresponding solution of hole forming in pile foundation is put forward to provide reference for the construction of similar projects in the future.

**Keywords:** cast-in-situ pile, obstruction, obstacles, hole form

Comparison and Analysis on Structural Forms and Construction Schemes of Underground Tank in Pumping Station ..... MA Chao ( 106 )

**Abstract:** In virtue of the design of rainwater pumping station in an railway underpass project, the differences between the open-excavated underground tank and open-caisson underground tank are compared. Firstly, starting from the structural stress, the stress conditions of the tank body in different forms are analyzed. Then, the engineering costs, construction periods, construction technical requirements and construction qualities of two forms of open excavation and open caisson are compared. The comparison results can provide the reference for the comparison of the structural forms and construction schemes of underground tanks in pumping station in the future.

**Keywords:** open-excavated underground tank, open-caisson underground tank, comparison and analysis of schemes

Study on Key Technologies of Axis Control of Curve Pipe Jacking in Shallow Overburden Soil ..... KONG Lei ( 109 )

**Abstract:** With the continuous deepening of urban development, the role of the pipe-jacking construction technique is more remarkable in the urban municipal pipeline and channel projects. Facing the more and more complex construction environment and social environment pressure, on the basis of the straight pipe jacking technique, the curve pipe-jacking construction technique solves the problem that the straight pipe jacking is hard to solve, plays the huge economic and social effects, and is also greatly developed. Based on its particularities of the project, two adverse factors of curve pipe jacking and shallow overburden soil should be overcome. Due to the great construction difficulties, it is required to strictly control the mechanical equipment modification, axis lofting, process measurement and deviation rectification, in addition required to ensure the protected structures within the curve. The construction technologies are expounded mainly from the aspects of axis lofting and traction control. The emphasis is on the site construction, which provides the reference for the construction of curve pipe jacking in the different environments.

**Keywords:** pipe-jacking construction, curve pipe jacking, shallow overburden soil, short distance

Numerical Calculation and Analysis of Deformation of Large-diameter Deep-sea Pipeline Laid by Floating Assistance ..... CHEN Kun ( 113 )

**Abstract:** Taking the Xuwei New District Up-to-standard Tail Water Sea-discharging Project as an

example, the laying construction of the discharge pipe in the deep-sea section is required to strictly control the bending curvature of the pipeline within the allowable range in order to ensure the safety of the pipeline, and the construction is very difficult. By introducing a deep-sea pipeline laying construction method suitable for the deep water conditions, the construction technological parameters are quantitatively calculated and analyzed, which can provide the reference for the similar projects.

**Keywords:** sea-discharging pipeline, deep-sea laying construction of pipeline, deformation control

Brief Analysis on Control Essentials of Cement Modified Expansive Soil Replacement Construction for River Slope  
..... XU Xin ( 118 )

**Abstract:** Focusing the expansive soil treatment in the great hydraulic engineering, the cement solidified method is used to modify the expansive soil. Considering in a certain aspect of practical site construction procedure and quality control essentials, the valuable practical experience of the expansive soil treatment study in many key projects is absorbed, which accumulates some experience for the supervision of the quality control in the construction of cement modified expansive soil.

**Keywords:** expansive soil, replacement construction, quality control

Experience in Design and Implementation of Deep Foundation Pit Support under Asymmetric Stress .....  
..... REN Dong ( 122 )

**Abstract:** In the development process of the area, the underground space is often connected as a whole, and the actual development progress of each adjacent plot is different, which leads to the asymmetry of soil and water pressure on the retaining structure of deep foundation pit implemented in the later stage. Based on a project case in soft soil area, the design essentials and later implementation effect of deep foundation pit under the condition of asymmetric stress are analyzed, which can be a reference for the other similar projects.

**Keywords:** asymmetric, deep foundation pit, support form, monitoring

Protection Scheme of Existing Underground Pipeline in New Urban Road Construction .....  
..... LIU Li ( 125 )

**Abstract:** According to the needs of city development, the urban road construction cannot be carried out with the development of surrounding land are at the same time. In engineering, there are often the existing pipelines under the construction land. Generally, the design scheme of protection or relocation is selected according to the buried depth and scale of pipelines, and integrating the engineering feasibility and economy. For the protection of large pipelines, the methods of protection pipe bridge culvert or light material replacement are usually used. Each method has its advantages, disadvantages and applicability. Based on the practical situation of the project, the reasonable technical schemes of pipeline removal or protection are discussed, which can be referred for the similar projects.

**Keywords:** road construction, underground pipeline protection, protection pipe bridge culvert, light material replacement

Design and Application of Form Traveler for Dismantling Continuous Beam Bridge .....  
..... SHENG Yanan, CHEN Dandan ( 129 )

**Abstract:** There are four continuous beams of the main bridge of the old Jingtai Bridge. The bridge spans the Xintongyang Canal. Its spans are 38.5 m + 60 m + 38.5 m. The total length of dismantling beam is 548 m. The reverse construction of form traveler is used to dismantle the continuous beam. The main equipment to dismantle bridge is the form traveler. The structure and application of this equipment are specially introduced, which provides the reference for the dismantling construction of the similar bridges.

**Keywords:** bridge engineering, form traveler for dismantling bridge, design, dismantle

Research on Safety Detection and Evaluation Method of High-pole Lamp Structure ..... YIN Wei ( 133 )

**Abstract:** There is no similar engineering experience for the safety detection of high-pole lamp structure in the industry. In the case of essentially blank in the existing methods, the basic condition survey, technical condition inspection, loading test, tilt monitoring and rating classification of the high-pole lamp are expounded and analyzed respectively and the safety detection and evaluation method of high-pole lamp structure are summarized and formed, which provide some reference for carrying out eh similar engineering detection projects in the industry in the future.

**Keywords:** high-pole lamp, lamp panel, jacking system, detection

Analysis on High-strength Bolt Disease of Bolting Steel-box Girder ..... PAN Sitong, Xia Tian, LI Zexin ( 137 )

**Abstract:** There are 439 sets of broken bolts and 16 073 sets of seriously corroded bolts on a bolted steel box girder with a main span of 618 m. The fracture reasons are analyzed from the aspects of initial material defects, processing technology, stress corrosion, mechanical properties and fatigue fracture by using the methods of disease investigation, metallographic analysis, chemical component analysis and finite element analysis. The results show that the bridge deck water seeps into the box girder from the connection joint at the pavement damage. The caused stress corrosion is the main reason to cause the fracture of the high-strength bolt of the bridge. Based on the analysis, the bolts with serious corrosion and fracture have to be replaced, and the seepage point is blocked, and the corrosion and fracture of high-strength bolt will be obviously reduced.

**Keywords:** cable-stayed bridge, bolting steel-box girder, high-strength bolt, corrosion, fracture

## STUDY ON SCIENCE & TECHNOLOGY

Cable Force Test Based on Video Sub-pixel Template Matching Algorithm ..... ZHOU Zijie ( 140 )

**Abstract:** Aiming at the cable force test of cable structure and based on the laboratory test, the computer vision method and the traditional acceleration sensor method are compared, and the applicability of computer vision method is discussed. It is studied the use of the servo static load anchor testing machine to tension a single steel stay-cable strand. The simulation of cable tensioning stress state is simplified. The dynamic response of cable is measured by the non-contact measuring method of camera photography. The dynamic deformation, base frequency and force of cable are identified by the sub-pixel template matching algorithm, and are compared with the test results of the traditional acceleration sensor. The study results show that the rumble spectrum peaks of cable identified by the computer vision method are obvious, and the identifying result of base frequency is basically same as the test result of acceleration sensor. The maximum error between the cable force identification result and the measured value is less than 6%, which has the ability to conduct the actual structural cable force test.

**Keywords:** cable force, non-contact measurement, computer vision, template matching, laboratory test

In-situ Test Study on Stress State of Soil Anchor Cable in Construction Process of Foundation Pit in Soft Soil Stratum ..... LIU Linqi, YE Kejiang, ZHAO Guoqiang, WANG Yingyi ( 144 )

**Abstract:** In view of the uncertainty of prestress loss and its support effect risk evolution of anchor cable support system caused by the construction disturbance of deep foundation pit in soft soil stratum, combined with the large deep foundation pit project of Wenzhou Airport, the in-situ test is carried out on the distribution characteristics and evolution of soil anchor cable prestress in the whole process of foundation pit excavation. Based on the real-time data, the variation characteristics of anchoring force in the process of foundation pit excavation, the influences of construction methods and parameters on the

anchoring force, and the influence of geometric parameters of anchor cable on its own force and effect are systematically studied. The results show that the excavation and unloading of soil in short distance has a great abrupt effect on the real-time anchoring force of the anchor cable system. With the excavation process of the foundation pit, the anchoring force of each sample increases slowly. The loss and increase of the anchoring force depend on the geometric parameters of the anchor cable structure. When the length of the anchor cable is greater than or equal to three times the depth of the foundation pit, the loss of anchoring force tends to zero and increases gradually. The results can be used for the reference in the design of anchor cable support of foundation pit in soft soil stratum.

**Keywords:** soft soil foundation pit construction process, soil anchor cable support effect, anchor force change, in-situ test study

Effective Distribution Width Calculation and Stress Analysis of Infinite Long Plate Strip with Counterpoint Load ..... SHI Jiangtao (150)

**Abstract:** The study of stress distribution of infinite long plate with the counterpoint load is helpful to further understand and solve the problem of lateral calculation simplification of long strip plate structures (such as bridge structures with overhanging beam). Its equivalent loading mode (plane stress problem) also corresponds to the force problem (plane strain problem) of soft soil subgrade with the subjacent under the strip foundation. Through the theoretical analysis, the method of complex variable function is used to obtain the stress calculation formula of the infinite long plate strip with counterpoint load, and then the effective-width simplified calculating method of the theoretical solution is derived. The error control of the theoretical solution is within 5%, which makes the theoretical preparation for further engineering application.

**Keywords:** complex variable function method, stress diffusion angle method, effective distribution width

Study on Elastic-plastic Earthquake Response of Monosymmetry Section Pier ..... WANG Wei (153)

**Abstract:** Based on the software OpenSees, the elastic-plastic fiber beam-column element is used to establish the pier column model. Considering the influences of upper beam weight, shock insulation support and material nonlinearity, the increment dynamic analysis (IDA) method is used to analyze the structural elastic-plastic earthquake response of a monosymmetry section pier. The calculation result shows that two-way bending is found when a monosymmetry section pier is under the unidirectional seismic action. Under the seismic excitation perpendicular to the axis of symmetry, the double-bending coefficient of pier will be reduced with the increment of PGA. After PGA reaches a value, the double-bending coefficient will not be greatly changed, which provides some references for guiding the design of the similar bridges.

**Keywords:** bridge engineering, pier, earthquake response, elastic-plastic, OpenSees

Study on Influence of Uneven Foundation Settlement on Upper Ferris Wheel ..... HUANG Yuanfei, CHEN Rongjun (156)

**Abstract:** In recent years, the number of rooftop ferris wheels integrated with commercial complexes has increased. Therefore, the analysis of the interaction between the ferris wheel and commercial complexes has become more important. The fixed-cable roof ferris wheel is mainly studied. Aiming at the uneven settlement of the ferris wheel foundation column points, the midas gen software is used to carry out the numerical simulation analysis on it, and the field measurement results are compared and analyzed with the simulation results. The results verify the rationality and reliability of the numerical model obtained from the simulation. The problem of internal stress caused by the uneven settlement of the foundation column points to the fixed cable of ferris wheel is solved. The relationship between the vertical tension and settlement of asymmetrically arranged cables is revealed. A method to solve the influence of uneven



settlement on the steel structure of the ferris wheel is proposed, which provide a useful reference for the design of the ferris wheel integrated with commercial complexes in Ningbo and other areas.

**Keywords:** ferris wheel, foundation settlement, Midas Gen, asymmetric, erticality, simulation

Study on Influence of Cushion Parameters on Bearing Characteristics of CFG Pile Composite Foundation

..... FU Hao ( 159 )

**Abstract:** In order to study the influence of physical parameters of cushion on bearing characteristics of CFG pile composite foundation, a finite element model of CFG pile composite foundation for a project is established by using MIDAS /GTS, and the settlement of foundation and the pile-soil stress ratio under different working conditions are analyzed. The results show that the foundation settlement and pile stress ratio increase with the increase of the upper load, and the cushion can reduce the foundation settlement. The larger the cushion thickness is, the smaller the foundation settlement is and the larger the pile-soil stress ratio is. The larger the cushion modulus is, the smaller the foundation settlement is and the larger the pile-soil stress ratio is. The selection of reasonable cushion parameters is helpful to adjust the proportion of pile-soil load sharing and give full play to the bearing capacity of foundation. Considering the range of economic benefit and safety performance, the cushion thickness of the project should be 400 mm, and the modulus should be 70 MPa. The reasonable design of the actual project has a guiding role.

**Keywords:** CFG pile composite foundation, cushion, settlement, pile-soil stress ratio

Study on Selection Method of Bridge Type Based on Adaptation Assessment .....

..... ZHANG Jinkang, ZHOU Qing, FU Chenxi, WU Yakun ( 163 )

**Abstract:** The selection of bridge type is a systematic decision-making process which contains many influence factors. In order to improve the objectivity and rationality of the bridge type selection, a selection model of bridge type with the whole life cycle adaptability as the assessment index is established. This model takes the adaptation assessment as the target layer and takes the safety, application, economy, durability, beauty and environmental protection as the criterion layer. On this basis, a method combining subjective and objective is introduced to determine the weight of evaluation indexes. Finally, the applicability of several common small and medium span bridges under the typical construction conditions is evaluated, and the feasibility of the type selection method is verified.

**Keywords:** bridge engineering, bridge type selection, whole life cycle, adaptation assessment, index weight

Study on Water Stability of Drainage Asphalt Mixture .....

..... LUO Qiang ( 167 )

**Abstract:** The drainage asphalt pavement adopts the gradation of large voids, which has the advantages of reducing the water area of rainy days, anti-sliding and reducing noise. For asphalt mixture with large voids, its water damage resistance is the key to determine the durability of pavement. The drainage asphalt pavement uses open-graded asphalt mixture, and the selected asphalt is the high-viscosity modified asphalt treated by characteristic modification. This kind of modified asphalt can be used in wet and dry processes. At present, there are many ways to prepare the drainage asphalt mixture by dry and wet methods. A comprehensive comparison of water stability performance for these methods will be carried out to provide the technical support for the engineering applications.

**Keywords:** drainage pavement, mixture, modifying agent, technology, water stability

Evaluation on High Temperature Performance of Asphalt Based on Dynamic Shear Rheological Test .....

..... JIN Yuefei ( 170 )

**Abstract:** As one of the input parameters for the design of asphalt pavement material, the high temperature

stability of the asphalt can ensure the serious rut disease not occurring within the service life of asphalt pavement. In order to explore the high temperature viscoelasticity of asphalt, three matrix asphalts and two modified asphalt are selected. The dynamic shear rheometer (DSR) is used to test its high temperature performance. The consistency of softening points, PG high temperature grading results and multiple stress creep recovery (MSCR) test results of different asphalts is compared. The result shows that the results obtained by using the different experiments have the consistency. The high temperature performance of the modified asphalt is better than the matrix asphalt. The softening point, rutting factor ( $G^*/\sin \delta$ ), and creep recovery percent (R) of modified asphalt are higher than the matrix asphalt, and the non-recoverable creep compliance ( $J_{nr}$ ) are lower than the matrix asphalt. Additionally, the test index based on DSR can better express the viscoelasticity property of the asphalt by comparing with the needle penetration and softening point, and can better simulate the rutting development process on the practical pavement.

**Keywords:** asphalt cement, PG high temperature grade, rutting factor, multiple stress creep recovery (MSCR) test

Study on Influence of Machine-made Sand Characteristics of Tunnel Slag on Concrete Slump .....

..... HUANG Wei, YU Deshui ( 174 )

**Abstract:** In order to dispose the slag produced by tunnel excavation, and to solve the problems of insufficient supply of and demand for the natural sand and high cost in the construction of mountain road, the tunnel slag from a tunnel excavation in Chi-qi Expressway is taken as the raw material to prepare the machine-made sand used into concrete. The influences of the stone powder content, grading, grain shape feature, MB value and other characters of the machine-made sand on the concrete slump are studied. The test results show that the slump of machine-made sand concrete increases first with the increase of stone powder content, and then decreases gradually when the content exceeds 5.4%. Among the three gradations listed, JP2 with the particle contents greater than 1.18 mm and less than 0.075 mm contribute greatly to the slump of machine-made sand concrete. The particle characteristics of machine-made sand have good linear correlation with slump. The larger the Mb value of machine-made sand is, the smaller the slump of concrete will be. The Mb value of machine-made sand should be controlled during production.

**Keywords:** machine-made sand, stone powder content, grading, characters of sand, methylene blue value

Design Method of Mini-type Steel-pipe Composite Anti-slide Pile Based on Equivalent Method .....

..... ZHANG Lubin, WANG Renpeng, LIU Jian ( 177 )

**Abstract:** The reasonable design theory and practical design calculation method have not been formed in the engineering application of mini-type steel pipe pile, and the design mostly relies on engineering analogy. Based on the equivalent method, the mini-type steel pipe composite anti-slide pile group and the rock-soil body are taken as a flexible anti-slide retaining wall. The general design steps of the mini-type steel pipe composite anti-slide pile are introduced, and combined with a project, the design calculation method of the mini-type steel pipe composite anti-slide pile is studied, which provides a reference for solving the similar engineering problems.

**Keywords:** mini-type steel pipe pile, equivalent method, computing method

## APPLICATION OF ACHIEVEMENTS

Application of Oblique Photogrammetry Technology in Expressway Reconstruction and Expansion Project

..... ZHANG Hongfei ( 180 )

**Abstract:** The traditional sense of surveying and mapping has been unable to meet the needs of the information age of intelligent surveying and mapping. The unmanned aerial vehicle (UAV) oblique

photogrammetry technology has brought the new technical means to the surveying and mapping industry. The application process of oblique photogrammetry technology in the actual surveying and mapping production project is studied. Through the calibration of aerial survey camera, the adjustment of aerial survey parameters, the optimization of image control point layout scheme and the strict checking and processing of data, the surveying and mapping results meeting the specifications and project requirements are finally obtained. Finally, the method is applied to the reconstruction and expansion of expressway, and the residual error statistics and error analysis are carried out on the data of field mark points, ground elevation, rainwater and sewage well location, expressway pavement bridge joints and other characteristic points. The results show that the accuracy of the measurement results of this method is reliable, which solves the problem that the traditional measurement method is hard to directly carry out the expressway measurement, improves the work efficiency and has good effect.

**Keywords:** oblique photography, 3D live-action model, expressway engineering, image control point

Research on Fast Measurement Method of Verticality of Pier Based on Vector Method .....

..... YUAN Xiaofeng, DENG Liyun ( 184 )

**Abstract:** In the process of bridge construction or operation management, the verticality of piers is one of the important control factors. On the basis of expounding the traditional measurement method of piers, a fast measurement method of pier verticality based on vector method is put forward by using 3D laser scanning technology. Combined with the actual measurement results of piers, it is concluded that the measurement results of this method are consistent with those of the traditional methods, and the measurement has high precision, which has a certain application prospect for the verticality measurement of bridge pier or similar high-rise buildings.

**Keywords:** verticality, pier, laser scanning technology

Application of Well-point Dewatering Technology in Municipal Road Engineering .....

..... ZHU Rongjun, ZENG Huifeng ( 187 )

**Abstract:** The southeast coastal area of China has become the first choice for the development of various industrial parks due to its unique geographical advantages. But its high groundwater level and soft soil bring some difficulties to the engineering construction. Through a project practice, the application of well-point dewatering technology in the municipal road construction is introduced. And the theoretical formula and finite element analysis are provided. It is shown that the well-point dewatering technology is suitable for a certain permeability of the soil. The method in subgrade construction and underground pipeline construction plays the roles of improving the soil engineering characteristics and ensuring the pipeline excavation construction smoothly. The method has good feasibility and economy.

**Keywords:** well-point dewatering, pipeline construction, municipal road

Application of New Interlocking Block in Small and Middle River Regulation Project .....

..... CHEN Jie ( 191 )

**Abstract:** With the development of social economy, the requirements of ecological environment and landscape effect for the regulation of small and middle rivers are higher and higher, and the ecological slope protection gradually appears in people's vision. The ecological slope protection structure commonly used in Shanghai in recent years is reviewed, and the interlocking block slope protection structure is discussed. Firstly, the structure type of the traditional interlocking block is briefly introduced, and its shortcomings are analyzed. And then the existing problems of the traditional interlocking block are optimized and improved to form a new interlocking block structure. Finally, combined with an engineering example, the practical application effect of the new interlocking block I introduced. Its effect can provide a reference for the design of small and middle river regulation projects in the future.

**Keywords:** river regulation, ecological landscape, ecological slope protection, new interlocking block

## THE RELATIVE SPECIALITIES

Overall Design of South China Expressway Shimentang Mountain Four-lane Tunnel Extension Project by New Austrian Method ..... ZHANG Weihua ( 194 )

**Abstract:** The total length of Shimentang Mountain Tunnel Extension Project is about 2 km. It is proposed to construct a 720-m long oversized-span single-hole four-lane tunnel, which is the first oversized-span tunnel newly built at the side of the existing multiple arch tunnel in China. After the implementation of the tunnel expansion project, the original two-way four-lane multi-arch tunnel will be combined into a two-way eight-lane section tunnel, which effectively opens the traffic bottleneck and alleviates the congestion problem at this place.

**Keywords:** overall design, super-large span tunnel, four-lane tunnel, multi-arch tunnel, New Austrian Method

Study on Structure Scheme of Urban River-crossing Tunnel under Complicated Conditions ..... ZOU Tao ( 198 )

**Abstract:** Taking a river-crossing tunnel in Shanghai as an example, the factors of fully using the underground space, playing the function of road traffic and protecting the surrounding environment are comprehensively considered. The open and underground excavation schemes of river-crossing tunnel are further compared. The open excavation scheme of laminated structure is determined. Its construction is combined with the cofferdam by frames. According to the surrounding environmental conditions, a reasonable support system is adopted for the foundation pit, and the whole process of foundation pit excavation is simulated numerically. The results show that the influence of excavation on the surrounding environment meets the requirements of the code.

**Keywords:** river-crossing tunnel, shield method, laminated structure, numerical simulation

Discussion on Reinforcement Design of Underground Road Structure ..... GU Zhichao ( 203 )

**Abstract:** On the basis of the existing research, for the structure of open-cut underground roads, the structural reinforcement design is discussed from the aspects of rigid zone, peak clipping, haunch, axial force, structural cavity, etc., and the multiple models are established for comparative analysis. The results show that in the design of the underground road structure, the beneficial effect of the haunch on the internal force and reinforcement of the structure should be considered so as to greatly reduce the amount of steel bars and the cost. When the subway earthing is thick, the structural cavities should be added to the municipal infrastructure around the structure to save the underground space resources and greatly reduce the engineering cost.

**Keywords:** underground road structure, rigid zone, peak clipping, haunch, axial force, structural cavity

A New Generation of Unmanned Toll Charging Robots ..... ZHANG Wenguang ( 206 )

**Abstract:** Since the network toll collection throughout the country, ETC lane has become the mainstream model of non-cash charges. But there are still some vehicles using cash, Wechat, Alipay and other payment methods. Under the new toll charging mode, the on-site toll collectors need to face more abnormal events with the increasing working pressure. How to relieve the working pressure of on-site toll collectors, to optimize the configuration of toll collectors and to reduce the operation pressure of enterprises have become the difficulties of each expressway management unit.

**Keywords:** unmanned toll charging, intelligence, robot

Settlement Plan of EPC—Engineering, Procurement, Construction for Municipal Project ..... TAO Jian ( 209 )

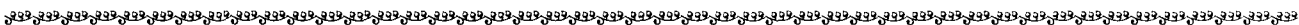
**Abstract:** The settlement plan is the plan and planning in advance for the project settlements. The settlement management philosophy is implemented in the whole process of project through the effective plan. Taking a municipal project as an object, the contents especially for attention in the settlement plan of EPC are analyzed to improve the management level of settlement.

**Keywords:** EPC (engineering, procurement and construction), EPC settlement, plan

Analysis on Cost Difference of Municipal Engineering between Shenzhen City and Main Cities in Guangdong Province ..... HE Jiayi ( 212 )

**Abstract:** Aiming at the problem of the municipal engineering cost index in Shenzhen City higher than the cost indexes in the main cities of Guangdong Province, combined with four ongoing projects of Shenzhen New City Interchange, Sili Road Reconstruction, Tonggang Avenue in Shenzhen–Shantou Cooperation Area and Shenzhen–Shantou Avenue, the main factors of cost different are analyzed from four aspects of labor cost, material expenses, quota level and local valuation.

**Keywords:** municipal engineering, analysis of cost difference



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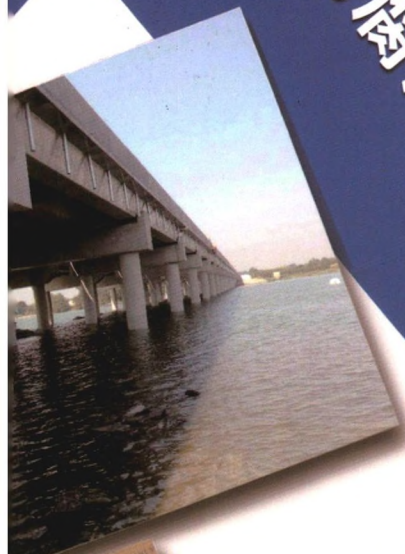
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